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Alaska Sewage Lagoons

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ALASKA SEWAGE LAGOONS

U. S. ENVIRONMENTAL PROTECTION AGENCY
ARCTIC ENVIRONMENTAL RESEARCH LABORATORY
COLLEGE, ALASKA 99701

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ALASKA SEWAGE LAGOONS

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for the

FEDERAL WATER QUALITY ADMINISTRATION

DEPARTMENT OF THE INTERIOR

ALASKA WATER LABORATORY

COLLEGE, ALASKA

Working Paper No. 8

ALASKA SEWAGE LAGOONS

There are many isolated communities and governmental installations in Alaska with populations of less than 1000 people. Most native villages are not sewered. A few of the government outposts are served by extended aeration package plants, others have septic tanks, and the rest have no treatment. Some of the septic tanks dump directly into the ground.

An aerated lagoon with its ability to handle overloads and its simplicity of operation is attractive for remote installations. Facultative lagoons with their extreme simplicity are also attractive for remote site application, especially areas where power is unavailable or extremely expensive ($0.25 to $1.00 per kilowatt-hour).

In 1957 a small facultative lagoon was placed in operation north of the Arctic Circle at Fort Yukon, Alaska. The system is a leaky lagoon (no definite effluent line exists) that serves a school.

Late in 1967 the Alaska Air Command and the Alaska Water Laboratory entered into an agreement to construct and operate a research field facility that included an aerated lagoon pilot plant at Eielson Air Force Base, 22 miles southeast of Fairbanks in Interior Alaska. Most of the information in this report has been obtained from the Eielson lagoon.

COLD REGIONS LAGOON EXPERIENCE HISTORY

When considering lagoons for Alaska and Northern Canada application, strong emphasis must be placed on cold weather impact.

Facultative Lagoons

The Northern Regions Sewage Lagoon Performance Statistics presented in Table 1 indicate a number of factors of importance: 1. winter BOD and solids removal efficiencies are not significantly improved by longer detention times in a single cell, but are significantly improved when a system has several cells operated in series; 2. BOD removal efficiencies are not affected by increases in lagoon depth; 3. bottom sludges will accumulate and their rate of accumulation will, in general, increase as one travels north, and the rates vary from 8.8 to 14.0 cu ft per 1000 people per day; and 4. although winter efficiencies for the removal of total coliforms are not well defined, winter removals of 97.7 to 99.9 percent were reported at Inuvik and Yellowknife. Pathogenic organisms have been isolated from the sewage deposits of early expeditions and camps in the Arctic and Antarctic many years after man's activities at the sites had ceased (2).

The actual lagoon size is directly proportional to the required system detention and the system cost is also directly proportional to the length of detention; therefore, loading rates become a highly important factor. Svore (29) found that loading rates are the key to odor control and states that "10 lbs applied BOD per acre per day usually eliminates Spring breakup odor problems; 20 lbs applied BOD per acre per day creates odor during Spring breakup of 1 to 2 weeks duration; 25-30 lbs applied BOD per acre per day creates odors of 3 to 4 weeks duration; and 50-60 lbs applied BOD per acre per day creates odors that persist for as long as 3 months." On the other hand, Brisbin (6), Dawson (7,8,9), and Higo (13) have found that odor control can be attained at much higher organic loading rates. At Moose Jaw, Saskatchewan, odor problems became so serious with a loading of 1080 lbs applied BOD per acre per day and 7 day detention that the lagoons had to be bypassed. The Sutherland, Saskatchewan lagoons operating at 1300 to 2600 lbs applied BOD per acre per day and detentions of 2.75 and 1.45 days seldom create odors detectable at distances greater than 1000 feet with detectable odors generally limited to distances less than 100 to 300 feet. Dawson (7,9) reports definite improvements at Yellowknife, Northwest Territories, when a short detention anaerobic primary cell (0.6 day detention and 8 ft depth) was added. Higo (13), after investigating a number of lagoons in Alberta, Canada, concludes that the potential for odor production can be minimized when designing short detention time systems by provision of central submerged influents, depths of 10-20 feet, detention of 2 to 4 days (not over 4 days at existing flows), and BOD loading not to exceed 9 lbs applied BOD per 1000 cu ft per day (4000 lbs applied BOD per acre per day at 10 ft depths).

Dawson (7,8,9) and Grainge (12) have found that stabilization lagoons operating under extreme winter conditions provide BOD and solids removal rates that are approximately equivalent to primary waste treatment.

Both North Dakota (31) and Minnesota (1,11) are recommending that stabilization lagoons be designed with sufficient volume to provide for retention of all winter flows; thus limiting effluent discharge to that period of the year when adequate treatment is obtained.

Aerated Lagoons

Aerated lagoons have operated successfully in cold regions of the contiguous United States and Canada for a number of years. The first aerated lagoon in Alaska was located at the Eielson Air Force Base, near Fairbanks, and operated by the Arctic Health Research Center.

The cost of construction of aerated lagoons is almost directly proportional to detention requirements; therefore, reasonable performance versus detention time prediction capabilities are necessary. Several investigations have collected data for aerated lagoon operation performance within the temperature range of 0°C to 10°C; selected sources are shown in Figure 1. The curves demonstrate that there is a high probability for obtaining BOD removal efficiencies greater than 80 percent at detentions less than 15 days with lagoons operating at temperatures less than 5°C.

Another factor affecting sizing of aerated lagoons is a volume requirement for bottom sludge accumulation. Reid (19) suggests that approximately 1/2 inch of annual sludge accumulation can be expected when a perforated tubing aeration system is utilized for aeration and mixing.

Although several different submerged aeration systems appear completely feasible for Alaska application, some of which have been used in Canada, only the performance of perforated plastic tubing manufactured by Hinde Engineering, Inc. has been reported in the literature. The results obtained by Reid (19), preliminary results of current Alaska Water Laboratory investigations, and aeration design approaches described by others (14,16), indicate that air delivery and placement are not nearly as critical for aerated lagoons as for extended aeration and activated sludge. Furthermore, system reliability is more important than its actual configuration for air delivery.

Although Reid (19,20,21) presents a strong case for the utilization of perforated tubing for aerated lagoons in cold regions, it is feasible to design other diffuser systems that will provide adequate mixing.

According to Van Heuvelen (31), "There are two waste treatment facilities of the diffused air tube type which have gone through several winters. The quality of effluent appeared to be satisfactory for the first year, but operation and maintenance problems increased and

TABLE 1. NORTHERN REGIONS SEWAGE LAGOON PERFORMANCE STA

(Compiled From Reports and Publications Referenced, in Last Line)[1]

	Inuvik, N.W. Territories	Yellowknife, N.W. Territories (before modification)	Yellowknife, N.W. Territories After Modification — Series Operation Primary Cell	Yellowknife, N.W. Territories After Modification — Series Operation Secondary Cell	Lacombe, Alberta (3140)	Drayton Valley, Alberta (3650) — Series Operation (Cell #2 out 12/20/61-4/11/62) Cell#1	Drayton Valley, Alberta (3650) — Series Operation (Cell #2 out 12/20/61-4/11/62) Cell #2	Drayton Valley, Alberta (3650) — Series Operation (Cell #2 out 12/20/61-4/11/62) Cell
Latitude, °N	68°21'	62°	62°	62°	52°	52°	52°	52°
January Average Air Temperature, °F	-28.2 (Fahr. -34.1)	-20.3 (Fahr. -28.2)	-20.3	-20.3	Edmonton +3.7	Edmonton +3.7	Edmonton +3.7	Edmonton +3.7
Lagoon Type	Facultative	Facultative	Anaerobic	Facultative	Facultative	Facultative	Facultative	Facultati
Lagoon Depth (ft.)	1.9-3.4	3.2	8.0	3.2	5.0	5.0	5.0	4.0
Detention Time (days)	73-136	134	0.6	99	202	52	33	36
Loading--#BOD$_5$/acre/day --#BOD$_5$/1000 ft.^{3}/day	8.9-9.6 0.082	15 0.108	5170-6170 11.9-14.2	18.8-19.4 0.136	25.7 0.118	88.5 0.255	Summer/Winter 26.9/62.0 0.124/0.286	Summer/Wi 9.2/ 38.0 0.04/0.2
Ice Conditions--Duration Starting Month to End Month --Depth (ft.)	October May To bottom except at inlet	October May 1-1/2	None 0	October May 1-1/2	November March 5.0	November April 2.0	November April 2.5	November April 2.5
Sewage--Source --Winter Temperature, °C	Raw Domestic 19°C	Raw Domestic <6.5°C	Raw Domestic <6.5°C	Primary Effluent <1.5°C	Raw Domestic 9-10°C	Raw Domestic --	Primary Effluent <1.0°C	Cell #2 Effluent <0.5°C
Lagoon Temperature--Summer, °C --Winter, °C	12.5-20°C <1°C	14-20°C 1°C	14-20°C 1°C	14-20°C <1°C	18°C <1°C	19-21°C 0.5-3°C	19-23°C 0.5-3°C	19-21°C 0.5-3°C
Operation Efficiency --BOD, Summer % Removed --BOD, Winter % Removed	73-89 41	70 41	36 36	75* (61)** 59 (35.9)	92.0 30.1	70.5 29.1	86.0* (82.5)** 40.8 (16.1	92.5* (88 53.5 (21
--Suspended Solids, Summer, % Removed --Suspended Solids, Winter, % Removed	92 85	-- --	-- --	-- --	76 68	61.1 69.2	56.6 (-11.5) 71.7 (8.1)	58.1 (3 72.7 (5
--Total Coliforms, Summer, % Removed --Total Coliforms, Winter, % Removed	99.7 99.9+	-- --	73 80	99.99 97.7	-- --	-- --	-- --	-- --
Odor Conditions Near Lagoons	Noticeable at 700 ft.	Definite Problem	None Reported	None Reported	Low Level	Low Level	Low Level	Low Level
Comments	Swamp area with brush and trees in lagoon	Nearly anaerobic with some exposed sludge banks	--	Natural lake with construction deficiencies	--	--	--	--
Bottom Sludge Accumulation, ft.^{3}/1000 capita/day	--	--	12.9	--	--	--	--	--
Information and Data Source Reference	Dawson, 1967	Dawson, 1967	Dawson, 1967		Higo, 1965	Higo, 1965		

[1]This table should be interpreted as a partial listing. *Total system efficiency at any stage **Removal efficiency of individual

	Sutherland (Saskatoon), Saskatchewan — Series Operation #1	Sutherland (Saskatoon), Saskatchewan — Series Operation #2	Portage LaPrairie, Manitoba	Fort Yukon, Alaska (School)	Lazy Mountain Children's Home, Palmer, Alaska	Camrose, A (7708) — Series Ope Primary #1	Camrose, A (7708) — Series Ope Primary #2	Camrose, A (7708) — Series Ope Secondary
Latitude, °N	52°	52°	52°	Arctic Circle	62°	52°	52°	52°
January Average Air Temperature, °F	-1	-1	--	-12	+12	Edmonton +3.7	Edmonton +3.7	Edmonton +3.7
Lagoon Type	Anaerobic	Anaerobic	Facultative	Facultative	Facultative	Anaerobic	Facultative	Facultati
Lagoon Depth (ft.)	17	17	--	3.0	2-5	10.0	10.0	5.0
Detention Time (days)	2.75-1.45	2.75-1.45	--	--	2+	6.2	5.75	3.45
Loading--#BOD$_5$/acre/day --#BOD$_5$/1000 ft.^{3}/day	1300-2600 3.5-7.0	-- --	80-80 --	85 (winter only) 0.75	40 0.46	Summer/Winter 808/808 3.71/3.71	Summer/Winter 488/514 2.24/2.36	Summer/Wi 697/754 3.20/3.46
Ice Conditions--Duration Starting Month to End Month --Depth (ft.)	None --	-- Periodic thin sheets	November April --	-- To bottom at edges	October April 2	November March Nil-0.3	November March Nil-1.0	November March 2.5
Sewage--Source --Winter Temperature, °C	Raw Domestic 10-14°C	Cell #1 --	-- --	School 20°C	School --	Raw Domestic + Milk Process. 14-16°C	Primary #1 Effluent 1-5°C	Primary #2 Effluent 1-4°C
Lagoon Temperature--Summer, °C --Winter, °C	-- 5-7.8°C	-- 2.8-4.5°C	-- --	-- <1.0°C	-- 1.5°C	17-23°C 1-5°C	17-23°C 1-4°C	17-23°C 0.5-3°C
Operation Efficiency --BOD, Summer % Removed --BOD, Winter % Removed	-- --	30-50 20-35	85-98 36	-- --	-- 35-50	44.5 41.2	55.1* (19.1)** 46.6 (9.2)	59.4* (9. 52.4 (10
--Suspended Solids, Summer, % Removed --Suspended Solids, Winter, % Removed	-- --	55-70 55-70	-- --	-- --	-- --	52.8 79.6	56.9 (8.7) 85.8 (30.4)	73.8 (38 87.1 (9.
--Total Coliforms, Summer, % Removed --Total Coliforms, Winter, % Removed	-- --	80-90 70-80	-- --	-- --	-- --	-- --	-- --	-- --
Odor Conditions Near Lagoons	Detectable at Less than 300'	Detectable at Less than 300'	None Reported	None Noticed	2 weeks in Spring	Moderate to High	Moderate to High	Slight
Comments	Noticed efficiency reduction w/length of service	Odors seem to be coming from floating grease, scum	Two ponds operated alternately	No overflow High groundwater area	--	School Load Plus Milk Processing Plant Sludge--thick, black Offensive odor to good draining fine dark		
Bottom Sludge Accumulation, ft.^{3}/1000 capita/day	14.0	--	--	--	--	9.5-10.1	9.5-10.1	--
Information and Data Source Reference	Brisbin, 1967		Sparling, 1961	Anderegg, 1960	Anderegg, 1959	Higo, 1965		

ORTHERN REGIONS SEWAGE LAGOON PERFORMANCE STATISTICS

(Compiled From Reports and Publications Referenced in Last Line)[1]

	Yellowknife, N.W. Territories — Prior Modification: Series Operation Primary Cell	Secondary Cell	Lacombe, Alberta (3140)	Drayton Valley, Alberta (3580) — Series Operation (Cell #2 out 12/20/61-4/11/62): Cell#1	Cell #2	Cell #3	Stettler, Alberta (3900) — Operated in Series: Primary #1	Primary #2	Secondary #1	Secondary #2	Norman Wells, N.W. Territories
		62°	52°	52°	52°	52°	52°	52°	52°	52°	65°
		-20.3	Edmonton +3.7	Edmonton +3.7	Edmonton +3.7	Edmonton +3.7	Edmonton +3.7	Edmonton +3.7	Edmonton +3.7	Edmonton +3.7	--
obic		Facultative	Facultative	Facultative	Facultative	Facultative	Anaerobic to Facultative	Facultative	Facultative	Facultative	Anaerobic
		3.2	5.0	5.0	5.0	4.0	10	5	5	5	2
		99	202	52	33	36	5.94	6.20	75.2	87.4	23
-6170 -14.2		18.8-19.4 0.136	25.7 0.118	55.5 0.255	Summer/Winter 26.9/62.0 0.124/0.286	Summer/Winter 9.2/ 38.6 0.05/0.222	1433 3.29	Summer/Winter 488 / 429 2.24 / 1.97	Summer/Winter 20.8 / 36.8 0.096 / 0.164	Summer/Winter 3.49 / 24.2 0.016 / 0.11	49 0.56
		October May 1-1/2	November March 5.0	November April 2.0	November April 2.5	November April 2.5	December February Short durations 0.3	December March 0.2-1.0	November April 3.5	November April 3.5	-- --
omestic °C		Primary Effluent <1.5°C	Raw Domestic 9-10°C	Raw Domestic --	Primary Effluent <1.0°C	Cell #2 Effluent <0.5°C	Raw Domestic + Milk Process. 8-11°C	Cell #1 Effluent 1.5-5°C	Cell #2 Effluent 0.5-3°C	Cell #3 Effluent 0.2-2°C	Airport --
°C		14-20°C <1°C	18°C <1°C	19-21°C 0.5-3°C	19-23°C 0.5-3°C	19-21°C 0.5-3°C	18-22°C 1.5-5°C	17-21°C 0.5-3°C	18-22°C 0.2-2°C	18-22°C 0.1-1°C	-- --
		75* (61)** 89 (36.9)	92.0 30.1	70.5 29.1	86.0* (52.5)** 40.8 (16.5)	92.5* (46.4)** 53.5 (21.4)	37.0 28.2	63.6* (42.3)** 37.3 (12.7)	93.0* (80.7)** 51.1 (22.0)	95.5* (35.7)** 73.0 (44.6)	-- 67
		-- --	76 68	61.1 69.2	56.6 (-11.5) 71.7 (8.1)	58.1 (3.4) 72.7 (3.5)	69.6 64.1	71.1 (4.9) 74.1 (27.9)	74.5 (11.8) 85.2 (42.6)	87.1 (49) 87.1 (12.8)	-- --
		99.99 97.7	-- --	-- --	-- --	-- --	-- --	-- --	-- --	-- --	-- --
Reported		None Reported	Low Level	Low Level	Low Level	Low Level	Moderate	Moderate	Nil	Nil	None Reported
		Natural lake with construc-tion deficiencies	--	--	--	--	Algae showed in this pond from April to fall	--	Storage with release spring and fall	Storage with release spring and fall	--
		--	--	--	--	--	8.75	--	--	--	--
Dawson, 1967			Higo, 1965	Higo, 1965			Higo, 1965				Dawson, 1965

*Total system efficiency at any stage **Removal efficiency of individual cell considering only the load that particular cell receives

	Fort Yukon, Alaska (School)	Lazy Mountain Children's Home, Palmer, Alaska	Camrose, Alberta (7708) — Series Operation: Primary #1	Primary #2	Secondary #1	Secondary #2	Long Detention #1	Long Detention #2	Eielson AFB Experimental System (Fairbanks Ak.
	Arctic Circle	62°	52°	52°	52°	52°	52°	52°	64°
	-12	+12	Edmonton +3.7	Edmonton +3.7	Edmonton +3.7	Edmonton +3.7	Edmonton +3.7	Edmonton +3.7	-10
otive	Facultative	Facultative	Anaerobic	Facultative	Facultative	Facultative	Facultative	Facultative	Facultative
	3.0	2-5	10.0	10.0	5.0	5.0	5.0	5.0	4.5
	--	2+	6.2	5.75	3.45	3.45	101	93	18
	85 (winter only) 0.75	40 0.46	Summer/Winter 808/808 3.71/3.71	Summer/Winter 488/514 2.24/2.36	Summer/Winter 697/754 3.20/3.46	Summer/Winter 590/693 2.71/3.18	Summer/Winter 135/23.4 0.062/0.107	Summer/Winter 2.1/21.6 0.01/0.10	125 0.637
er	-- To bottom at edges	October April 2	November March Nil-0.3	November March Nil-1.0	November March 2.5	November April 3.0	November April 3.0	November April 3.0	November April <1.0
	School 20°C	School --	Raw Domestic + Milk Process. 14-16°C	Primary #1 Effluent 1-5°C	Primary #2 Effluent 1-4°C	Secondary #1 Effluent 0.5-3°C	Secondary #2 Effluent 0.5-3°C	Long Det. #1 Effluent 0.1-2°C	Air Base Domestic 21°C
	-- <1.0°C	-- 1.5°C	17-23°C 1-5°C	17-23°C 1-4°C	17-23°C 0.5-3°C	18-23°C 0.5-3°C	19-23°C 0.1-2°C	19-23°C 0.1-3°C	19-21°C 1°C
	-- --	-- 35-50	44.5 41.2	55.1* (19.1)** 46.6 (9.2)	59.4* (9.6)** 52.4 (10.9)	77.6* (44.7)** 52.8 (0.8)	96.3* (83.5)** 60.3 (15.9)	49* (98.1)** 71.5 (28.2)	73 51
	-- --	-- --	52.8 79.6	56.9 (8.7) 85.8 (30.4)	73.8 (39) 87.1 (9.2)	79.0 (19.8) 91.0 (30.2)	77.7 (-6.2) 91.8 (8.9)	92.7 (67.3) 93.6 (21.8)	87 87
	-- --	-- --	--	--	--	--	--	--	--
ad	None Noticed	2 weeks in Spring	Moderate to High	Moderate to High	Slight	Slight	Not Noticeable	Not Noticeable	None Reported
ds ad alter- y	No overflow High ground-water area	--	School Load Plus Milk Processing Plant Sludge--thick, black Offensive odor to good draining fine dark						Bottom sludge taken in Jan. & Febr. had 80% volatiles
	--	--	9.5-10.1	9.5-10.1	--	--	--	--	--
ing, 1961	Anderegg, 1960	Anderegg, 1959	Higo, 1965						Rubel, 1965

the quality of the effluent decreased. The holes in the tubing were subject to clogging and the recommended cleaning method did not open them up. The compressors had to work under a higher pressure to overcome the additional back pressure caused by the holes being plugged. The additional maintenance caused considerable concern to the owners of these installations." In regard to cleaning procedures for the perforated plastic tubing diffuser systems, Stewart, City of Regina, Saskatchewan (28) states, "The chief mechanical problem we have encountered is due to the small holes in the aeration tubing becoming blocked. It has been necessary to lower the water levels in the lagoons to clean the tubing holes, either by cutting new holes or by deforming (bending between two rollers). It appears in our case that deforming the tubing gave more lasting results."

Black (5) reported successful operation of a Welles floating aerator at Hinton, Alberta and a Lightnin fixed unit at Prince George, British Columbia in exposed temperatures of -29°C to -35°C.

Solids separation devices located in short detention primary cells (12 to 36 hour) followed by short detention aerated lagoon secondary cells (3 to 5 days) show considerable promise. Rupke (23) considers systems with the dividing wall being the solids separation system to be feasible provided adequate mixing in the primary cell is provided.

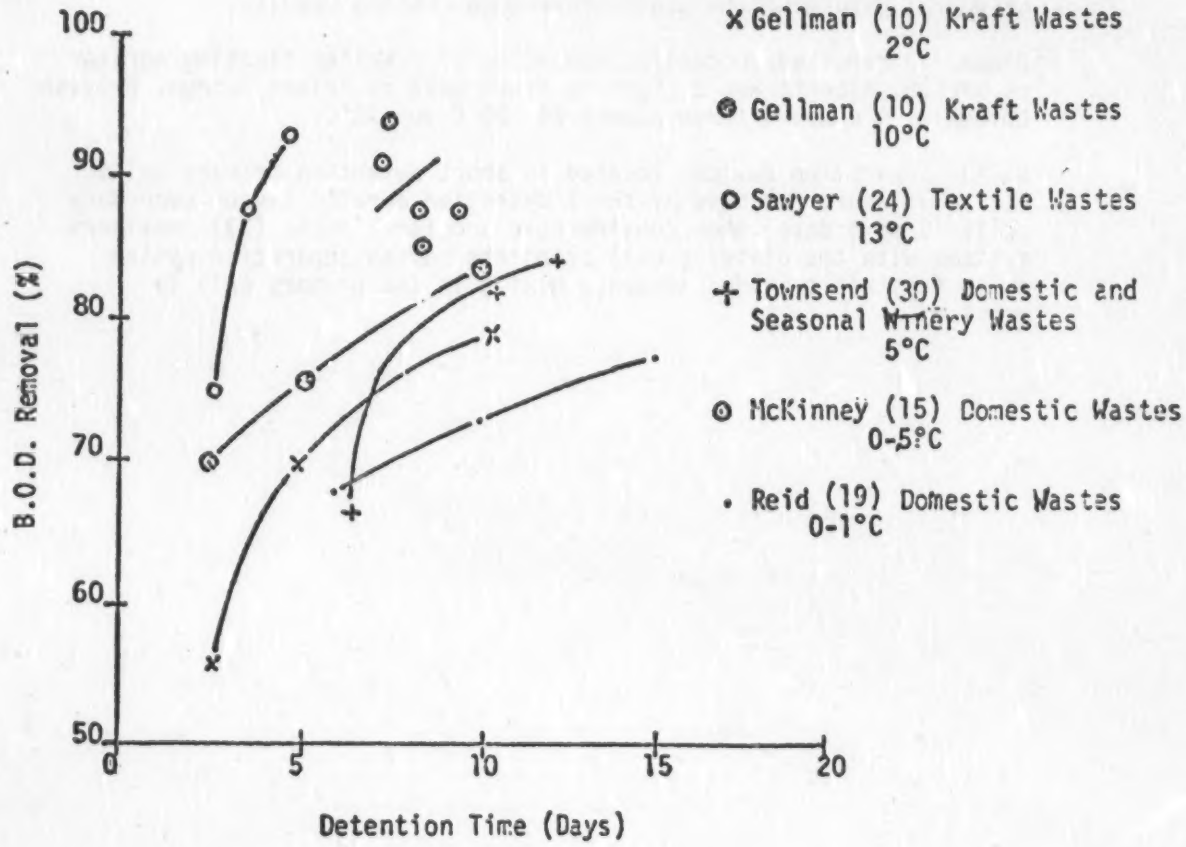

FIGURE 1

AERATED LAGOONS
PERFORMANCE EFFICIENCIES

ALASKA WATER LABORATORY

EXPERIMENTAL AERATED LAGOON PERFORMANCE

The experience to be discussed in this section has been acquired with a research pilot facility that was constructed jointly with the Alaska Air Command at Eielson Air Force Base (EAFB), 22 miles southeast of Fairbanks, Alaska.

The climate at EAFB, located at 64 1/2°N latitude, is continental including extreme temperatures of -80°F to +100°F with a mean annual temperature of approximately 25°F.

The research pilot lagoon located at EAFB was constructed with vertical walls to avoid an appropriate side-wall influence when scaling up to actual system size. The EAFB lagoon is a 20 mil PVC-lined wood crib structure, 14 feet deep, 15 feet wide, and 82 1/2 feet long. Operating depth is 12 feet. The lagoon is divided into 6 cells in series. The system has been operated with a total detention of 30 days (ice influence not recalculated) and accumulative detentions of: 1.8, 4.7, 8.3, 13.7, 21.0, and 30 days. Raw domestic sewage is utilized as feed. Flow measurement is accomplished with a dump tank and a timer on the feed pump and is checked by measuring effluent flow with a V-notch weir. Periodic leak tests are conducted to further varify flow through validity. In the lagoon, each cell in series is fed from the previous cell through a 2 in. diameter, 10 ft. long hose. Commercial perforated tubing was the first aeration device evaluated. It is 2/8 in. flexible plastic tubing with 8 1/2 slits per foot. The tubing is supported on wires 16 inches above the bottom. to alleviate sludge plugging, cell 1 has 14 tubes; cells 2 through 4 have 8 tubes; and cells 5 and 6 have 4 tubes. The second aeration system now under investigation utilized open valve disc air diffusers. This diffuser is essentially a 2 1/2 in. diameter shrouded disc, which sits on the open end of a 1/8 in. NPS pipe threaded into a header. The disc has a lift of 1/6 in. during full open air flow and "seals" the 1/8 in. pipe opening when the air is shut off.

Tha facility was placed in operation during the Winter of 1968-69. System efficiencies for BOD reduction are presented in Figure 2. During the winter, the temperature in the first 2 cells is a transition temperature from 20°C down to less than 5°C. The normal winter operating temperature for an aerated lagoon in Alaska varies from approximately 0° to 5°C. A close look at the family of curves in Figure 2 indicates several things. 1. There is a decided lag between winter removal curves and the summer removal curve. A small portion of this lag can be attributed to the ice influence on actual detention time, starting with cell 3. High among the potential explanations for the remaining lag are a lag in bacterial population build-up, created by low temperatures; depressed winter DO (0 a high percentage of the time) in cells 1 and 2 (tube clogging); and lower endogenous respiration rates at lower temperatures. 2. Summer BOD

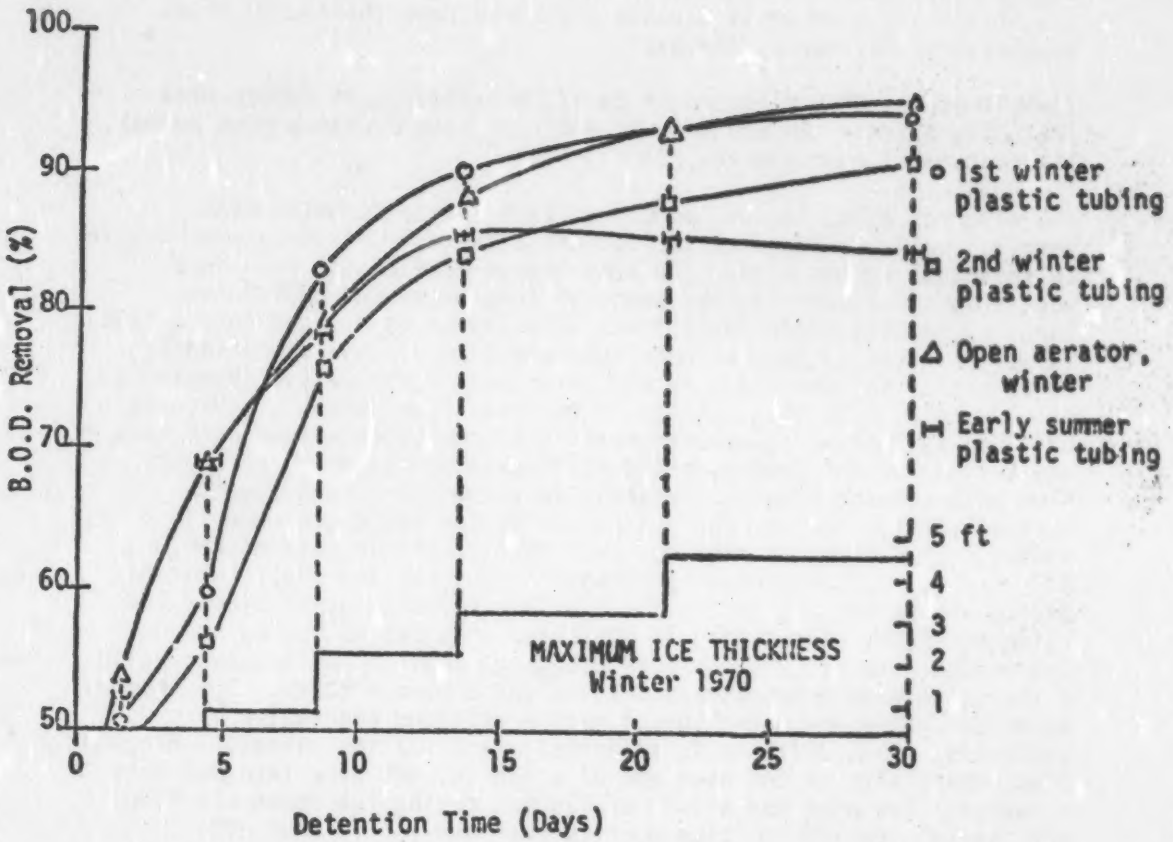

FIGURE 2

AERATED LAGOONS
B.O.D. REMOVAL EFFICIENCIES

removal efficiencies peak out between 15 and 20 days detention and drop off beyond 20 days detention. This is believed to be due to the effects of excessive algae growth. As the summer curve is for the first summer's operation and very little sludge had an opportunity to settle out in the last 3 cells, bottom influence is not believed to be significant in explanation of the summer efficiency reduction at higher detention. Algae were present in cells 2, 3, 4, 5, and 6 from mid-April to late September. 3. The second winter's data show consistent BOD removal efficiency reduction of approximately 5 percent below the first winter curve when perforated tubing provided the aeration and mixing. 4. The winter BOD removal efficiency curve for valve disc open aerators shows a significant improvement over the second winter perforated tubing system, and the valve disc open aerator curve is approximately the same as the first winter perforated tubing curve. 5. Maximum ice thickness of 4 1/2 feet to 5 feet may be expected near the effluent.

Preliminary results of tests with the system converted to a 4 cell system of the same detention time indicate that removal efficiencies for a 4 cell system are similar to those of a 6 cell system.

The total coliform removal efficiencies and effluent numbers are:

January-February	99.70%	$3x10^5/4$/100ml
March	99.97%	$2x10^4$/100ml

Contamination from the extended aeration effluent backing up during early January as a result of the common outfall, undoubtedly influenced these values. Summer 1969 effluent measurements for fecal indicators were:

	July	August
Total Coliforms	$5.5x10^3$ organisms/100 ml	$1.2x10^3$ organisms/100 ml
Fecal Coliforms	440	700
Fecal Enterococci	126	64

At the EAFB aerated lagoon, with 10 1/2 feet submergence, 0°C, 2-10 mg/l DO, and 80+% BOD removal, the tubing transfer efficiency calculates out to approximately 1 to 2 percent. No credit has been assumed or provided for surface transfer of BOD removal by primary sedimentation. (Ultimate BOD assumed to be 1.5 times the 5-day, 20°C BOD).

Current operating experience, using perforated tubing at the EAFB aerated lagoon has required frequent repair and maintenance. There have been considerable tubing clogging problems which have sent more than one compressor to the graveyard. The first attempt at HCl (gas) cleaning was successful but very shortlived as the tubing reclogged in less than two weeks. Before gas cleaning the perforated tubing, orifice pressure drop was greater than 3 psi at an air capacity of 1.5 cu ft per minute per 100 feet of tubing. After the first dose of gaseous HCl, the air rate increased by 50% with no change in pressure drop. The compressor discharge temperature was greater than 200°F at 9 psig with ambient air temperatures of 10 to 40°F.

NORTHWAY, ALASKA AERATED LAGOON PERFORMANCE

Northway, Alaska is located in Interior Alaska near the Canadian border. The coldest temperature in the United States has been recorded at Northway, which is -82°F.

The Northway lagoon is a bentonite-lined wood crib structure 42 feet by 54 feet by 7 1/2 feet operating depth. It has a longitudinal baffle, splitting it in two cells, 21 feet wide. Operation started during September 1965. Perforated plastic aeration tubing provides aeration and mixing with the spacing being according to the manufacturer's recommendations.

The Northway lagoon raw sewage averages approximately 240 mg/l BOD. Feed temperatures vary between 2°C and 25°C. The BOD removals at Northway do not vary significantly for summer or winter figures, with an average removal of 77% in the first cell and a total of 85% removal. According to the Site Manager (26), tube clogging has been a major problem, and the use of HCl (aqueous) has not been very effective. The Northway lagoon started out as a 30 day detention system but a decreasing population has reduced the load to the present 60 to 70 day detention system.

In June 1967 sludge core samples were examined and appeared to be preserved exactly as deposited. However, in August 1967 and May 1968, bottom samples had a definite black appearance and the physical characteristics of partially digested sludge. Significant methane production occurred during the summer of 1967. The maximum depth of bottom sludge did not increase, but its location shifted between the August 1967 and May 1968 sample dates. This shifting seems to indicate that gas production resuspends bottom sludge and thus assists in providing aerobic and anaerobic digestion.

The mixing action of aerated lagoons allows the sludge zone temperature to rise above 12°C during the months of June, July, and August and part of September in Interior Alaska. Maximum bottom temperatures recorded at Northway were 19°C. Samples taken during March 1970 at Northway indicate a sludge accumulation of approximately 6 inches in the first cell and approximately 3 inches in the second cell. For 4 1/2 years, this indicates an accumulation rate of 1 inch per year, or approximately 9 cu ft per 1000 people per day. This is less than observed rates for most stabilization ponds. It is difficult to predict what the long range accumulation and comparison will be. However, since the system is essentially a eutrophic lake, one would expect continued and accelerated bottom deposit build-up.

A Northway bottom sludge core sample taken in March 1970 from the first cell was sectioned and analyzed for fecal indicator bacteria. The 9 in. core was cut in three sections as follows: 0-3 inches bottom; 3-8 inches mid; and 8-9 inches top layer.

GENERAL ALASKA

AERATED LAGOON EXPERIENCE

Aerated lagoons started in Alaska with the successful operation of a small unit at Eielson Air Force Base specifically placed in operation for research purposes in 1964. Reid (19,20) studied the small lagoon located at EAFB and reported BOD removal efficiencies of 68-90% and solids removal efficiencies of 67-68% for winter operation, with primary settled sewage loadings of 68-200 lbs of BOD per acre per day (0.4 to 3.1 lbs applied BOD per 1000 cu ft per day). He found that loading rates between 0.4 and 2.4 lbs applied BOD per 1000 cu ft per day gave efficiencies of 60-80% BOD removal. The system was initially a single cell system with a depth of 4.4 feet and a surface area of 0.13 acres; later this was changed to a two cell system. If we assume that the data presented by Reid (19,20) are for treatment of raw sewage, expected winter efficiencies should range between 58% at 6 days and 78% at 37 days.

There are 17 aerated lagoons in Alaska at the moment. All but one use the perforated tubing for aeration and mixing. Their locations are shown on Figure 3 and listed below.

No. on Map	Location	Operating Agency
1	Amchitka	AEC
2	Annette Island	FAA
3	Bethel	FAA
4	N. Kenai	Big Bear Oil Refinery
5	Cold Bay	FAA
6	Cordova	FAA
7	Security Squad (Elmendorf AFB)	AAC
8	Eielson AFB	AAC-FWQA
9	Fire Island (Anchorage)	FAA
10	Fort Greely	U.S. Army
11	King Salmon	AAC
12	McGrath	FAA
13	Northway	FAA
14	Prudhoe Bay	Private Construction
15	Scenic Park (Anchorage)	Public
16	Wildwood (Kenai)	AAC
17	Yakutat	FAA

The Alaska Water Laboratory has obtained information for seven of the aerated lagoons, which serve mainly military and FAA sites, located at Northway, McGrath, Cold Bay, Bethel, Fort Greely, Eielson Research Facility, and Fire Island. Perforated tubing was used in all cases. Performance data to establish the efficiency of these lagoons are very limited, but basically they have shown good results in the first year or so of operation.

Organism Density

MPN counts on a per wet gram basis

	No. of organisms x 10^3		
	Top	Mid	Bottom
Presumptive Total Coliform	4.9	49	22.1
Confirmed Total Coliform	3.3	13	13
Fecal Coliform	2.4	4.9	3.3
Presumptive Enterococci	13	221	172
Confirmed Enterococci	13	221	172

It appears that the sludge located deeper in the core has a more favorable environment for preservation of fecal organisms. These bottom cores represent a stable bottom uninfluenced by resuspension dating from mid-September 1969 or 7 months of low temperature. The sludge temperature was less than 1°C and only one of four cores from the first cell at Northway had a pH less than 7.0.

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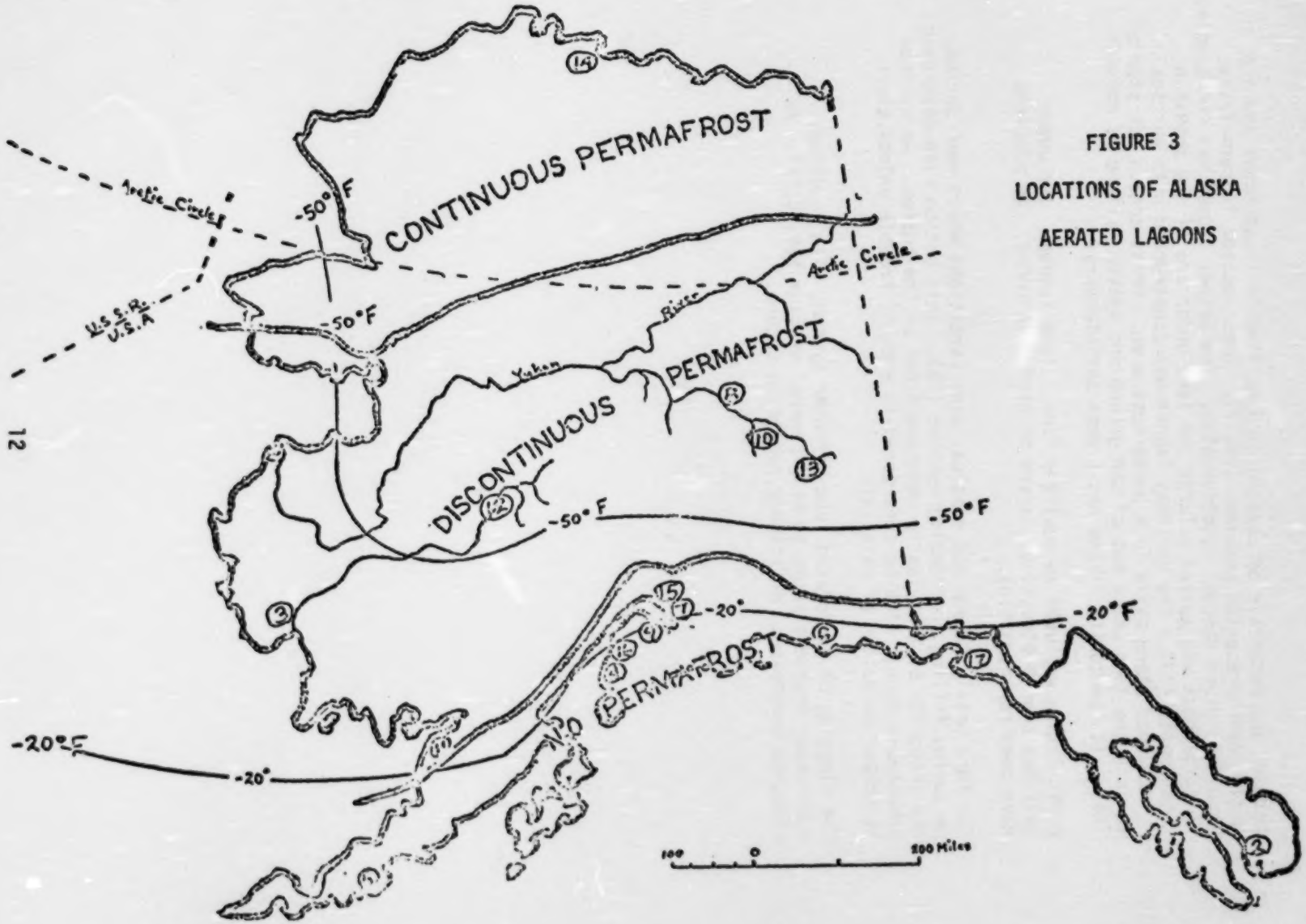


FIGURE 3

LOCATIONS OF ALASKA

AERATED LAGOONS

Methods and materials of construction related to frost-heave and ice action have presented problems (26,17). Construction in permafrost should be given special consideration. The Bethel lagoon was constructed in permafrost and melted a large ice lens under one of the retaining embankments (17). The Northway lagoon was constructed with vertical 3 inch wood plank walls in a permafrost area. Frost action has started to jack the long walls out of the ground and system failure is eminent (26). Its bentonite lining has proven satisfactory.

A PVC lining was used to seal the Fire Island lagoon. Its upper half has been protected by layers of hand laid rocks. No problems have been reported (18).

The Fort Greely lagoon had vertical wood partitions which were jacked up during filling in freezing weather (25). This action also destroyed the integrity of the plastic membrane liner on the bottom. An earthen embankment should also be considered an area of trouble unless there is proper selection of materials.

The clogging of perforated tube diffuser systems with resultant compressor problems seems to be a general problem (26,18,17). As clogging progresses, efficiency reduction occurs.

FORT YUKON

FACULTATIVE LAGOON PERFORMANCE

Fort Yukon, Alaska is located north of the Arctic Circle and has a continental climate. Although the recorded extremes do not match Northway for low or Fairbanks for high, the average annual temperature is lower than either Fairbanks or Northway and the probability of extended cold periods is greater.

The Fort Yukon facultative lagoon came into existence in 1957 under an experimental classification. Although it has an experimental classification, very little actual operating data have been collected. The Alaska Water Laboratory has initiated a study to obtain performance data for an annual cycle of operation. Results from the first field trip are presented in Figure 4 and Table 2.

The contributing population equivalent of 63 people provides a loading of 124 people per acre and is calculated as follows:

	Fraction day	No. of people	Fraction year		Pop. Eq.
Student Population	1/2	200	180/365	=	50
Adult/Winter	1	15	270/365	=	11
Adult/Summer	1	6	95/365	=	2
					63 total people

$$\text{Average annual sludge accumulation} = \frac{15{,}900 \text{ cu ft}}{\substack{63 \text{ people} \\ 14 \text{ years}}} = \frac{18 \text{ cu ft}}{\substack{\text{person} \\ \text{year}}}$$

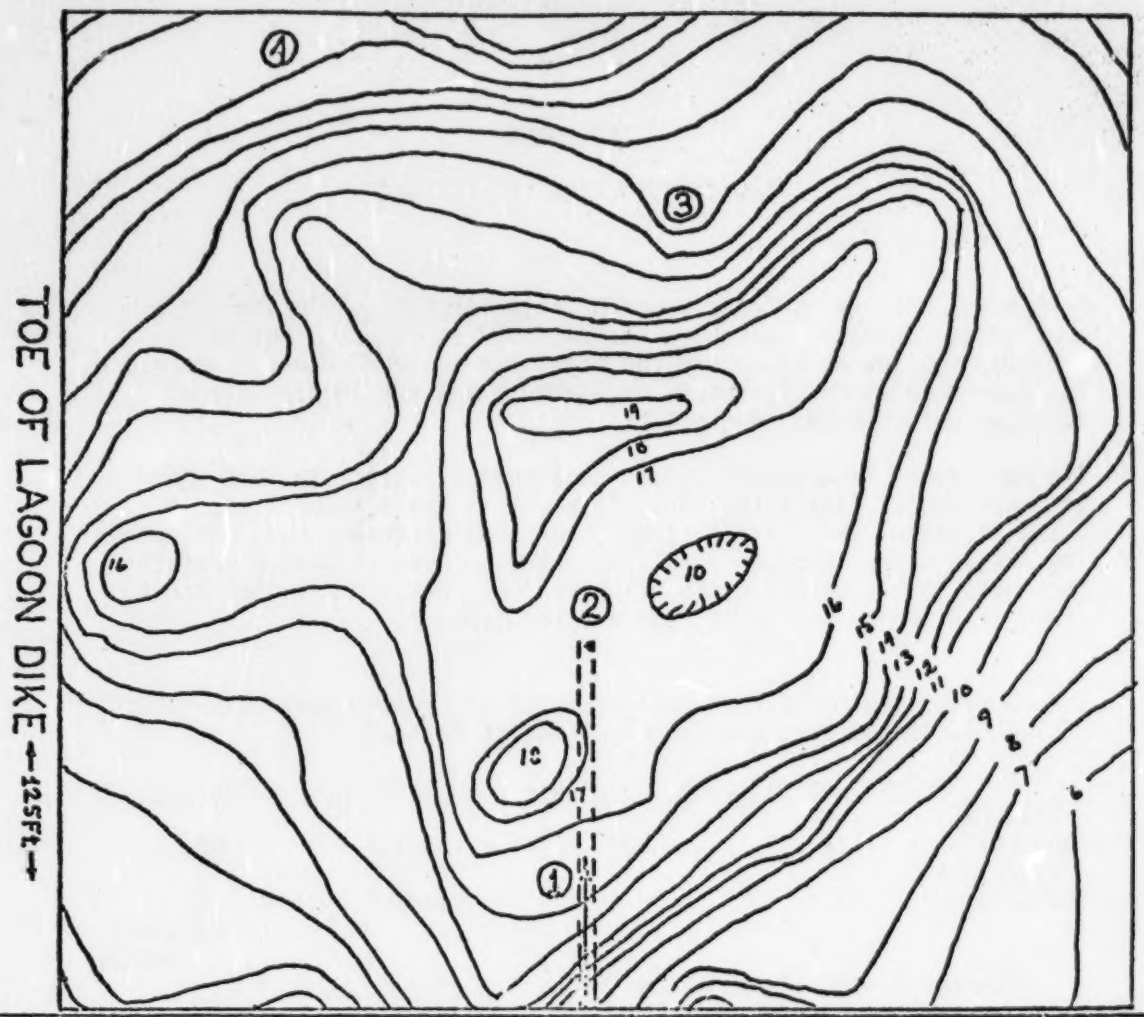
Lagoon size: 125'x125'x8' deep; 3:1 slopes

Winter surface loading: (125+24)(125+24) = 22,200 sq ft

$$\frac{22{,}200}{43{,}500} = 0.51 \text{ acres}$$

$$\text{Winter loading: } \frac{63}{0.51} = \frac{124 \text{ people}}{\text{acre}}; \text{ say 100-150}$$

The lagoon at Fort Yukon had an operating water depth of 8 feet in March 1970. Conversations with maintenance people at the school indicate that the lagoon depth decreases through the summer when there is no loading. The lagoon does not have an effluent, so performance figures have little meaning. The approach taken with this "leaky" lagoon has worked at Fort Yukon, as evidenced by the lack of concern by Fort Yukon residents about the lagoon existing within their community.



Stn. No.	Liquid / Sludge	COD	BOD	Total Solids	T. Volatile Solids	Suspend. Solids	Vol. Susp. Solids	pH	Coliform (Fecal)
1	Liquid	160 mg/l	87	450 mg/l	198 mg/l	31 mg/l	20 mg/l	7.03	—
	Sludge	20 mg/gm	—	wt. % H_2O 34%	wt. % Volit. 3.2%	—	—	6.67	13×10^4/gm
2	L	241 mg/l	48	571 mg/l	201 mg/l	33 mg/l	11 mg/l	7.13	—
	S	10 mg/gm	—	wt. % H_2O 28%	wt. % Volit. 1.9%	—	—	7.23	17.2×10^3/gm
3	L	219 mg/l	117	514 mg/l	156 mg/l	47 mg/l	16 mg/l	7.10	—
	S	—	—	—	—	—	—	—	—
4	L	204	100	556 mg/l	209 mg/l	35 mg/l	12 mg/l	7.02	3.2×10^6/ml
	S	12 mg/gm	—	wt. % H_2O 24%	wt. % Volit. 2.1%	—	—	7.09	19×10^3/gm

FIGURE 4

BOTTOM SLUDGE DEPTH PROFILE (in inches)
FORT YUKON LAGOON
APRIL, 1970

TABLE 2

ENTERIC INDICATOR BACTERIA IN SLUDGE

FORT YUKON SEWAGE STABILIZATION POND

Counts obtained per gram of sludge by MPN method

Sample Location (See Figure 4)

	1	2	4
Presumptive Total Coliforms*	1,300,000/gm	22,100/gm	7,900/gm
Confirmed Total Coliforms*	490,000	10,900	7,900
Fecal Coliforms*	130,000	1,720	4,900
Presumptive Enterococci*	700	240	240
Confirmed Enterococci*	310	33	49
Clostridia**	5.3×10^5	4.5×10^4	6.3×10^4

No Salmonella found in the samples**

*Dr. R. Gordon, Research Microbiologist, Alaska Water Laboratory, provided these analytical results.

** Mr. L. Miller, Chief, Bacteriology Section, Arctic Health Research Center, provided these analytical results.

CONCLUSIONS

Aerated Lagoons

Aerated lagoons, when properly designed, are simple, reasonably efficient waste treatment systems suitable for small communities. Aerated Lagoons, unlike facultative lagoons, do not require large surface areas, have odor problems, or have a high level of bottom sludge accumulation. Experienced operators are not required, as a properly designed system is extremely simple to operate.

With large exposed areas, ice will form to depths of greater than 4 feet on aerated lagoons. Spring thermal expansion of ice layers may create considerable strain on embankments, especially vertical walls.

Uitlizing gross bubble air diffuser systems, BOD removals of 80% to greater than 90% are feasible during the winter, depending on the number of system cells in series, individual cell detention time, and total system detention time. With perforated tubing (restricted) diffusers, BOD removals of 70 to 85% are to be expected depending on system configuration, detention time, and age of the aeration system. BOD removals greater than 86 to 88% are not feasible during the summer because of the algae load. When a restricted (partially clogged) aerator was used, the BOD removal efficiency was observed to drop as the lagoons age. The maintenance and clogging problems encountered with the restricted aeration system have not been found with the open type.

Provision of a system with a treatment efficiency (BOD removal) greater than 80% greatly increases the project's first cost (construction) but does not significantly increase operating costs.

Two lobe, positive displacement compressors will provide satisfactory performance without being enclosed in a heated building. High operating pressures greatly increase compressor maintenance problems. At 9 to 13 psig (clogged aeration system), discharge temperatures are over 200°F; at 5 to 6 psig, discharge temperatures are less than 90°F when outdoor ambient temperatures are 10-40°F.

Aerated lagoons are not efficient nutrient removal systems. On an annual basis, phosphates are removed during the summer and released during the winter, causing an apparent winter increase, but the annual net removal is essentially zero. Total nitrogen removals were approximately 30% in the summer and 0% in the winter.

Facultative Lagoons

There are four important considerations in the design and use of anaerobic and facultative lagoons for waste treatment.

Public Health Implications: Anaerobic and facultative lagoons are a definite improvement over disposal to the street, back yards, or an outdoor privy. The application of these systems to waste disposal in remote villages, where a source of reasonably priced power supply is unavailable, should be given serious consideration. Bottom sludge definitely accumulates faster than it is stabilized, so the system will have to eventually be abandoned. The question then becomes one of "how much public health hazard does an abandoned sewage lagoon create?" Deep, lightly loaded lagoons will have many years of service. Information on the degree of winter removal of coliforms is extremely scarce; however, there does appear to be a significant reduction. Pathogenic organisms have been isolated from early expeditions and camps in the Antarctic and Arctic, indicating long survival under refrigerated conditions.

Nuisance Potential: Anaerobic and facultative lagoons should always be located downwind (prevailing) and at least 1/4 mile from the nearest inhabitants. An obvious and reasonably reliable means for minimizing odor production is the utilization of a design loading of 20 lbs BOD per acre per day or less. However, Alberta and the Northwest Territories have had reasonable success in minimizing odor production through utilization of deep primary cells loaded at high rates (1 to 4 day detention), followed by long detention time cells in series. The reasons why a short detention primary cell usually will not produce large amounts of odor are not clear. It is undoubtedly a combination of factors, two of which may be high flow rates in the overlying liquids and the concentration of potential odor production in a small area.

System Loading and Process Efficiency Requirements: The evidence for utilizing anaerobic and facultative lagoon design loads of less than 50 lbs BOD per day per acre is overwhelming. However, the favorable experience with several cells in series and utilization of a short detention time (1 to 4 days) deep primary cell is reasonably well documented, and should not be overlooked. Winter BOD removal rates of 80-90% are not feasible; therefore, serious consideration must be given to winter storage with summer treatment in a shallow lagoon, where a two cell system is feasible.

System Configuration and Construction: The influence of ice cover, frost-heave, and depth must be carefully considered in the physical design of lagoons for an extremely cold climate. Influent, cross-over and effluent lines should be submerged, with the influent line centrally located. Canadian experience indicated that deep lagoons are preferable; however, the question exists, "what influence does the increase in depth have in the formation of a strong thermocline?" Extreme care must be exercised in application of lagoons in permafrost areas, where ice-rich soil may exist.

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